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Art. IX.—*The Shore Platforms of Mt. Martha, Port Phillip Bay, Victoria, Australia.*

By J. T. JUTSON, B.Sc., LL.B.

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Contents.

Introduction.

The writer has previously considered (1) in a general way some of the wave-cut rock platforms of Port Phillip Bay and its immediate vicinity. The present paper is intended to be the first of a series systematically describing the main platforms of the Victorian coast.

The bearing of the facts here recorded on the question of the recent emergence of the shoreline is reserved for later discussion.

General Description of the Mt. Martha Coast.

The coast-line described stretches north-westerly from the north-east corner of Dromana Bay, on the eastern side of Port Phillip Bay, to Martha Point, and thence north-easterly to just beyond Martha Cliff, which is a short distance south of the mouth of Balcombe Creek, a total distance of about three and a half miles (fig. 1).

Along this line the granodiorite dome of Mt. Martha is betrunked by cliffs, which are due to marine abrasion. The Mt. Martha dome is separated from the similar dome of Mt. Eliza to the north, and from the granite dome of Arthur's Seat to the south, by belts of low-lying country, more or less covered by recent deposits.

The Mt. Martha coast is exposed to the action of powerful waves which are developed by the strong southerly and south-westerly winds which sweep across the bay. The average range of the tide is from 2 to 3 feet.

The important aspects of the Mt. Martha granodiorite for the purposes of this paper are its system of joints and its degree of weathering at various points along the coast-line.

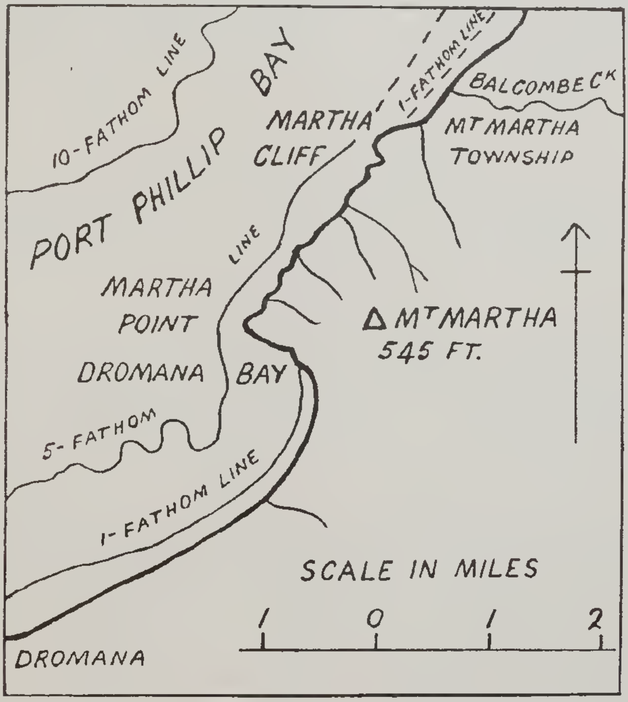

FIG. 1.—Map of the Mt. Martha coast.

The granodiorite is much and, in places, irregularly, jointed, but the strongest and most persistent joints are those which are vertical or close to the vertical. These vertical joints cut one another at various angles but two sets approximate towards a right angle.

The inner portion of the granodiorite up to varying heights above sea level (with perhaps a maximum of 30 feet, but this is a mere approximation) is a tough, practically undecomposed rock, highly resistant to erosion. The outer shell is decomposed and at each end of the outcrop, that is, to the immediate south of Balcombe Creek and just to the north of Dromana, the decomposed rock passes below sea level to an unknown depth (fig. 2). Decomposition is greatest at the extreme northern and southern ends of the rock mass.

The north-westward-trending coast (which may for convenience be termed "the southern coast") has at its south-eastern end a platform cut in decomposed granodiorite at the foot of fairly low cliffs (pl. VIII, fig. 1). This platform may be termed "the southern platform", and is later described. North-west from the platform the cliffs steadily rise to a height of 40 or 50 feet. They are steep and, in most portions, are covered by vegetation to within 3 or 4 feet of their base. Occasionally, a rocky bare cliff 8 to 10 feet high appears, above which is the vegetated steep slope.

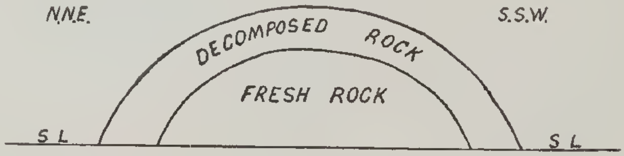

Fig. 2.—Diagrammatic section through the granodiorite dome of Mr. Martha. *S L*, sea-level.

In places at the foot of the cliffs just mentioned sharp projections or buttresses (the crests of which vary in height from approximately 2 to 10 feet above mean sea-level) of the undecomposed granodiorite occur, separated from one another by tiny bays and gulches (pl. VIII, fig. 3), the latter in some cases ending in tunnels ("caves") the position and outlines of which are generally determined by the vertical or nearly vertical joints. The gulches are up to 30 feet in length and are a few feet deep and wide. The "caves" penetrate the cliffs for about 6 feet and reach the same figure in height. The buttresses run out to sea, approximately at right angles to the coast-line, for about 30 feet and are from 4 to 20 feet wide. They have a rough outline, owing to the absence of strong horizontal joints and to the existence of close-set irregular ones in addition to the vertical master joints. The buttresses may become isolated from the cliffs and so form stacks, which in turn may be worn down to reefs.

Towards Martha Point traces only of a wave-cut rock platform are found.

In some of the small bays masses of coarse shingle, the components of which are fresh granodiorite with diameters up to 12 inches or more, are thrown up on the beach to the base of the cliffs; and similar shingle also rests in moderate quantities on the platform of decomposed rock mentioned above. In addition there are many rounded boulders of the fresh granodiorite up to 4 feet in diameter. These are either blocks broken away along joint planes with their corners rounded by the sea, or masses due to spheroidal weathering, which is well shown *in situ* at the foot of the cliffs. It may be noted that the term "shingle" is used in this paper as a general term to cover pebbles and boulders from an inch to about 18 inches in diameter.

Treating now the north-eastward-trending coast, which may be referred to as "the western coast", a platform cut in the decomposed granodiorite occurs to the south and east of Martha Cliff.

It may be termed "the northern platform". It generally resembles the southern platform, except that the steep cliffs behind it are higher than those flanking the southern platform. The remainder of this part of the coast has high cliffs composed of the fresh granodiorite in their lower portions and of decomposed granodiorite in their upper portions, the lower portions being, as a rule, steeper and with less vegetation than the upper portions.

This western coast, other than its northern end, has a crenulated outline, similar to that of the southern coast, except that the gulches are deeper, wider and longer, and the buttresses have a maximum greater width (some have been noted up to 30 feet wide) than those of the southern coast.

Shingle occurs on the western coast, usually in small quantities, in the little bays and between the buttresses (pl. VIII, fig. 2), but within a mile south of Martha Cliff there are some substantial banks. The shingle consists of fresh or somewhat decomposed granodiorite with occasional pebbles of ferruginous grit and sandstone. It also occurs, in a few instances, on the northern platform.

Along the western coast no platform in the fresh granodiorite is visible at the foot of the cliffs, except occasional patches a few square yards in area.

In their early form the buttresses have no uniformity in height, and their surfaces slope seaward at a moderate angle to the horizontal (pl. VIII, fig. 2). The occurrence of the buttresses is due to the action of the sea in creating gulches along comparatively weak areas of the fresh rocks, and to the stripping by atmospheric erosion of the softer material above the projections. This process continues until a buttress or a portion of it becomes low enough to be attacked by the sea, when it may be reduced almost to a horizontal plane and gradually lowered until it becomes a reef, which may in turn be removed by the waves (pl. VIII, fig. 4).

Progradation has taken place to a small extent in places along the southern coast.

The form of the cliffs and the abundance or scarcity of vegetation growing thereon reflect the character of their component rocks. Thus the cliffs of granodiorite decomposed to below sea-level are steep owing to the rapid undermining at their base, and are comparatively bare of vegetation on account of their steepness (pl. VIII, fig. 1). They have a young shore profile. The cliffs with fresh granodiorite at their base, and decomposed granodiorite above are steep in their lower hard portions, but moderately inclined and covered with abundant vegetation in their upper softer portions. They have a shore profile which, broadly speaking, is early mature.

The sea, even when moderately smooth, reaches the headlands and the heads of the gulches and small bays between the buttresses. In the larger bays of the southern coast, especially where banks of shingle occur, it is probable that only at rather exceptionally high tides or during storms do the waves reach the foot of the cliffs.

The cliffs less resistant to erosion with their accompanying well-developed wave-cut platforms are composed of brown rocks (decomposed granodiorite) and the more resistant cliffs, with few visible traces of wave-cut platforms, are in their lower portions, composed of grey rocks (fresh granodiorite). It will be convenient to refer to these two types in this way.

It may here be noted that the brown rocks in places at the foot of the cliffs have become somewhat tough again by the introduction of iron oxide.

The Nature and Mode of Formation of the Platforms.

The Normal Platforms.

The southern platform commences at the north-eastern corner of Dromana Bay, whence it runs continuously north-westerly for about 100 yards (pl. VIII, fig. 1). Thence it occurs at intervals in the same direction for some distance. Its average width is probably less than a chain and its surface, although generally very level, is broken in places by small stacks up to 8 feet high Heavy granodiorite shingle covers certain areas.

The northern platform, which lies to the east and south of Martha Cliff, is about 500 to 600 yards long and averages perhaps from a chain to one and a half chains in width. It carries small stacks a few feet high.

Both platforms are exposed at low tide, but are not covered by every high tide. They have been cut by the sea in the brown rock, in which the degree of decomposition varies, the most decomposed rocks along the coast-line occurring at the northern and southern ends of the granodiorite dome. This feature is reflected in the surface character of the platforms, in that the more decomposed the rock, the smoother the platform. This is especially noticeable in the northern platform where, at its southern end, there are pronounced irregularities—both major and minor—on its surface. These gradually decrease northward until, where the platform runs east from Martha Cliff, most of the major projections are smoothed away and only very minor ones remain. These minor ones, however, make in parts an unusually irregular platform surface within low vertical limits. To a less extent, the same features are repeated on the southern platform. No " rampart " similar to that described by C. K. Wentworth (2) occurs at the outer edge of either platform.

Where the granodiorite is thoroughly decomposed at the extreme southern end of the dome, the rocks are so easily removed that a platform is cut at a lower level than the normal platforms here described, and becomes covered with detritus.

The platforms are practically horizontal (pl. VIII, fig. 1) except, in places, for a width of a few yards at the base of the cliffs, whence they slope seaward at angles varying from about 5° to 8° similarly to the ordinary sandy beach. This is a common feature in most of the Australian platforms that the writer has examined. As the platform advances landward this sloping area will be planed down to the general level, but a new narrow area slightly inclined seaward will be formed immediately in front of the cliffs as the latter retreat landward. This narrow sloping strip coincides with Wentworth's "abrasion ramp" (2) and is due to wave planation.

At their landward edges the platforms are flanked by moderately high, steep cliffs of the brown rock and at their seaward edges the platforms descend sharply into the sea to a depth of from 4 to 10 feet, according to the distance any particular portion of the edge is from the high tide shoreline (fig. 3). (The sea bottom off the edge of the normal platforms is part of what is later described as the "ultimate platform"). The seaward edges of the surfaces of the platforms are very uneven, owing to the action of the waves in locating differences of resistance to erosion in the component rocks.

In the production of the normal platform, the comparative softness of the rocks nullifies the effect of geological structure and enables the sea to produce a platform with a relatively smooth surface exposed between tide marks (pl. VIII, fig. 1).

The normal platforms are constantly being extended landward by abrasion by the sea at the foot of the cliffs, and are constantly being destroyed at their seaward edges by the sea's attack (fig. 4). For a platform to exist, the rate of advance landward must at some period have been greater than the rate of destruction seaward. Once, however, the platform is established, it may widen or narrow, or eventually disappear altogether, according to the lithological nature and geological structure of the rocks at various points. Thus, if the component rocks of the cliffs changed from "soft" to "hard" rocks, erosion (other things being equal) would slow down and the rate of advance be retarded, and if at the same time the outer portion of the platform were or became composed of "soft" rocks, the rate of erosion would be either actually or relatively increased, with the result that the platform would become narrower. Conversely, if the component rocks of the cliffs became less resistant to erosion and the rocks at the seaward edge were or became more resistant to erosion, the rate of advance would be accelerated and the platform would widen. Further changes in the respective rates of erosion would bring about further changes in the width of the platform, with the possibility always of its disappearance and later re-birth. Alteration in the geological structure of the rocks and other factors, such as changes in the direction or power of the waves, might also check or hasten the growth of the platform.

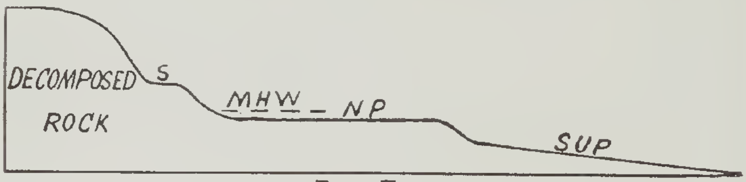

Fig. 3

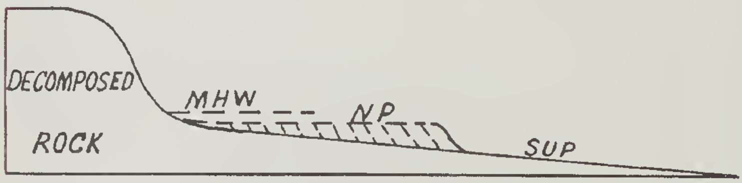

Fig. 4

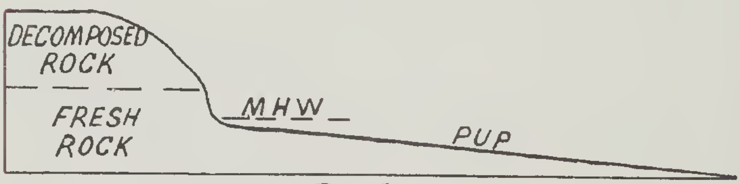

Fig. 5

FIG. 3.—Diagrammatic section showing the shelf, *S*; the normal platform, *N P*; the secondary ultimate platform, *S U P*; and the steep cliff, all in the decomposed rock. *M H W*, mean high-water level.

FIG. 4.—Diagrammatic section showing the removal by marine abrasion of the normal platform, *N P*; the extension thereby of the secondary ultimate platform, *S U P*, to the steep cliff, all in the decomposed rock. *M H W*, mean high-water level.

FIG. 5.—Diagrammatic section showing the formation in the fresh rock of the primary ultimate platform, *P U P*; the short steep cliff in the lower fresh rock; and the comparatively gentle slope of the cliff in the upper decomposed rock. *M H W*, mean high-water level.

It might be noted that exposure of the rocks at low tide will, to some extent, bring about their alternate wetting and part drying, which may aid in the disintegration of the rocks and thus facilitate their removal by the waves. This process however does not fulfil the conditions of water-levelling, including the presence of an outer rampart, as laid down by Wentworth (2). Since also the platforms are not solution benches (Wentworth (3)), wave planation is regarded as the dominant factor not only in the production of the abrasion ramps, but of the normal platforms as a whole.

THE ULTIMATE PLATFORM.

The ultimate platform, as here defined, is that rock bench which is almost entirely hidden from direct observation being, except at its extreme landward edge, generally covered by the sea, even at low water (pl. VIII, figs. 2, 3, 4). It appears to have a fairly rapid fall seaward, and is thus in marked contrast with the normal platform. In fact, it resembles the platform figured in nearly every geological text-book, although, so far as the immediate vicinity of the shore is concerned, it is probably the exception rather than the rule.

The ultimate platform has two aspects: First, as a primary platform, in that a normal platform has apparently never preceded its formation (fig. 5). Secondly, as a secondary platform in that the normal platform is first cut and the ultimate platform results from the destruction of the normal platform (figs. 3 and 4). These two aspects will be separately dealt with.

The ultimate platform as a primary platform.—This platform occurs off the middle portion of the Mt. Martha coastline, where the grey rock occurs at sea-level and for some height above it, and where there is no development of the normal platform.

Observation shows that the sea does not wear down the grey rock to a smooth plane, inclined or horizontal. The process by which destruction takes place may be described as quarrying (pl. VIII, fig. 2). The sea, armed with detritus, erodes channels along the strong vertical or nearly vertical joints and the channels gradually lengthen, widen and deepen. There are numerous, moderately widely spaced cross joints, either inclined at various angles or approximately horizontal; many close-set irregular joints also occur, these joints in some instances being not more than 3 inches apart. When the sea has worked along the vertical joints for some time, a block, from 2 or more feet to 3 inches across in any direction, can be dislodged by a violent blow of the waves, or by gradual undermining. The dislodged block is then further attacked and is eventually removed as shingle or sand. The result is that the surface of the grey rock tends to be irregular, especially in view of the fact that there is no system of strong horizontal joints.

There must be lines of weakness in the grey rock, although the latter appears to be homogeneous, since the sea acts selectively in cutting the deep and wide gulches between the buttresses as already described.

These processes therefore militate against the formation of an even-surfaced platform exposed at low tide, except in very limited areas, as, for example, at the foot of the cliffs in the small bays and between the buttresses, where such surfaces, sloping upward to the cliffs at angles of from 5° to 8°, occur, and form abrasion ramps. Similar surfaces of small area can be seen under water at low tide (though even these surfaces are marked by sand and shingle). The sea, however, is encroaching on to the cliffs and therefore a platform is being cut which is not open to direct observation, and the surface of which may be very irregular. Since also the sea-bottom gradually deepens, the platform must have a steady fall seaward and extend in that direction, but how far, will depend on the position of the shoreline at the commencement of the present cycle of marine abrasion. Whether the platform is free from, or covered by, detritus is at present unknown. Doubtless both conditions occur. Probably also, on the whole, the platform is being steadily degraded.

The retreat of the cliffs is slow compared with that of the cliffs flanking the normal platforms. This gives the sea time to cut more deeply, and so form the primary ultimate platform without the production of the normal platform as a temporary feature.

The ultimate platform as a secondary platform.—This class of platform is formed by the abrasion by the sea at a lower level than the normal platform (figs. 3 and 4), and with apparently a steady fall seaward similar to that of the primary ultimate platform. The difference between the two types of the ultimate platform is that the primary platform is cut in the grey rock without any relation to the normal platform, whereas the secondary platform is cut in the brown rock subsequently to the formation and results from the destruction of the normal platform.

Usually the secondary ultimate platform on its landward side abuts against the low cliff at the seaward edge of the normal platform, which the sea is constantly cutting away. In this manner the secondary ultimate platform grows landward. So long as the rate of advance of the normal platform at its landward edge is equal to or greater than the rate of destruction of the same platform at its seaward edge, the normal platform will intervene between the cliffs and the secondary ultimate platform. If, however, the converse happens, then the normal platform will disappear and the secondary ultimate platform will reach the shore (fig. 4). This has happened to the northern normal platform in some tiny bays where the conditions to ensure such a result have been favourable. In that case the secondary ultimate platform will generally resemble the primary one, except that possibly the surface below water of the former will be smoother than that of the latter.

The manner in which the normal platform may be widened, narrowed, totally destroyed and re-born is outlined above under the heading of the normal platforms.

Shelves above the Normal Platforms.

Towards the southern end of the northern normal platform there are a few short shelves a few feet wide rising to 8 feet above that platform (fig. 3). They are free from detritus (although above the shelves detritus occurs on the cliff face and the ledges projecting therefrom) thereby indicating the fact that the sea, by waves or spray, reaches these shelves and, by the removal of the debris formed by atmospheric erosion and perhaps even by direct abrasion, is mainly responsible for the occurrence of the shelves. That the spray reaches the shelves is shown by the presence of living marine mollusca there, as well as by direct observation.

Summary.

At the northern and southern ends of the granodiorite dome of Mt. Martha the rock at the coast-line is decomposed ("soft") but between these outcrops it is fresh ("hard").

An almost horizontal platform (the normal platform) cut in the soft rocks at each extremity and backed by steep cliffs of the same class of rock, is exposed at low tide.

The coast-line of the hard rocks is broken into a series of tiny bays and gulches, between which are pronounced buttresses. A platform cut in this hard rock by the waves slopes steadily seaward and its fall is so comparatively rapid that, except at the heads of the small bays and gulches just mentioned, it is not exposed at low tide, thus offering a marked contrast with the normal platform. It coincides with the wave-cut platform of the text books and, since it appears to be both an original and (as regards the present cycle of erosion) a final form, subject to its gradual lowering if not protected by marine deposits, it is termed a primary ultimate platform.

The normal platform, although it is advancing at its landward edge, yet is being destroyed at its seaward edge, and another platform, due to such destruction, is being cut in the soft rocks at a lower level and appears to slope steadily seaward. This lower platform is another type of the ultimate platform but, since it is of secondary origin, it is termed a secondary ultimate platform.

The decomposed rocks favour the formation of a coast-line, mostly smooth in outline; of the normal and secondary ultimate platforms; and of steep cliffs with scanty vegetation. Geological structure has apparently little influence on the making of those features. On the other hand, the hard rocks and their geological structure favour the formation of the contrasted crenulated coastline; of the primary ultimate platform; and, except in their lower portions, of sloping cliffs with abundant vegetation.

The normal platforms are due to wave planation, and the ultimate platforms to the quarrying action of the sea and wave planation combined.

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2. Wentworth, C. K. Marine Bench-forming Processes: Water-level Weathering. *Journ. Geomorphology*, Vol. 1, pp. 6-32, 1938.
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Explanation of the Plate.

Plate VIII.

Fig. 1.—The north-east corner of Dromana Bay. The normal platform and the steep cliffs, all cut in the decomposed granodiorite.

Fig. 2.—South of Martha Cliff. The sloping vegetation-covered cliffs; the buttresses of fresh granodiorite, with the alternating gulches at the foot of the cliffs; and the small bay, with shingle covering a strip of the primary ultimate platform, which rapidly falls beneath the sea.

Fig. 3.—East of Martha Point. A succession of buttresses, planed almost level by the sea, and gulches in the fresh granodiorite, being transient features in the formation of the primary ultimate platform.

Fig. 4.—South of Martha Cliff. A further stage in the formation of the primary ultimate platform. The buttresses of fresh granodiorite are mostly reduced to small reefs.


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